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INNOVATIONS AND APPLICATIONS 2

Effect of UV treatment on formation of disinfection by-products in chlorinated seawater swimming pools

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Abstract

A laboratory scale study has been conducted to analyse the effect of UV irradiation on the formation of several DBPs in seawater pools. The pool samples were collected from three indoor public seawater pools and exposed to two different UV doses and then chlorinated in dark for 24 h. In this study, effect on the formation of various volatile disinfection by-products e.g. trihalomethanes (THM), haloacetonitriles (HAN) and haloacetic acids (HAA), were observed in laboratory experiments using medium pressure UV treatment after post-UV chlorination. Results showed that post-UV chlorine demand was increased, dose dependently, with UV treatment. Results also indicated that post-UV chlorination induced formation of several DBPs. However, the formation of HAAs were decreased significantly, dose dependently, with post-UV chlorination which could also mean that HAAs decomposition might occur due to heat from UV exposure. Furthermore, the breakage of HAAs molecules into smaller molecules would also mean that they resulted an increase in THMs. Overall, the formation of HAAs were decreased but the formation of THMs and HANs were increased with post-UV chlorination. There is need to standardize the application of UV system in the seawater pool.

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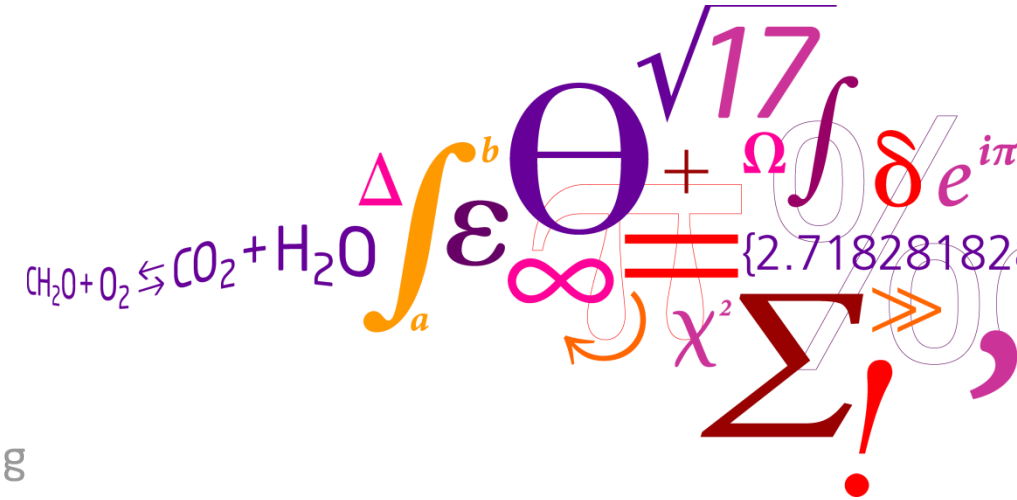
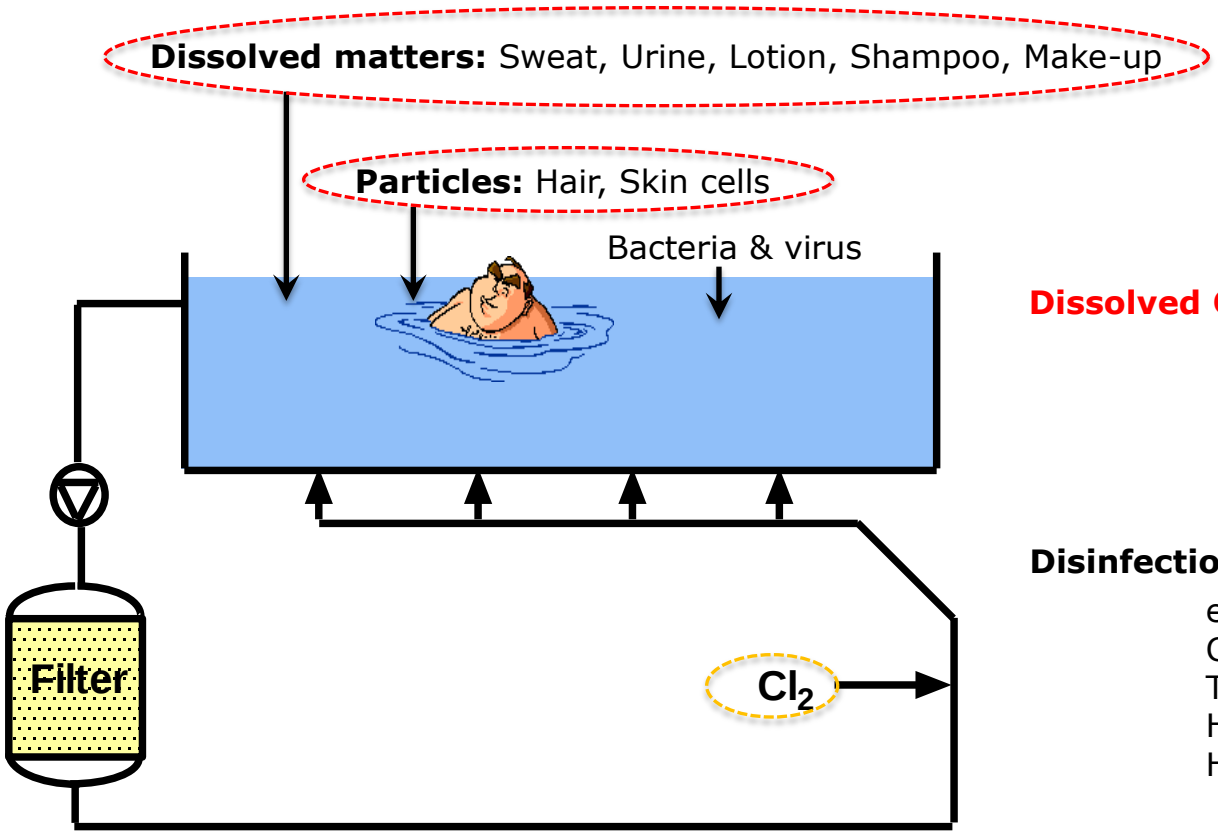
2017 IUVA Americas Conference
February 5-8, 2017
Austin, Texas
USA



DTU Environment
Department of Environmental Engineering

Disinfection By-Products



Dissolved Organic Carbon (DOC)
+
Chlorine

Disinfection By-Products (DBPs)

e.g.
Chloramines
Trihalomethanes
Haloacetonitriles
Haloacetic acids

Seawater Pools
Brominated DBPs

Skin conditions & wounds

Hay fever & sinus issues

Meditation & relaxation

Composition of seawater (mg/L)

Source: Water Condition & purification, 2005

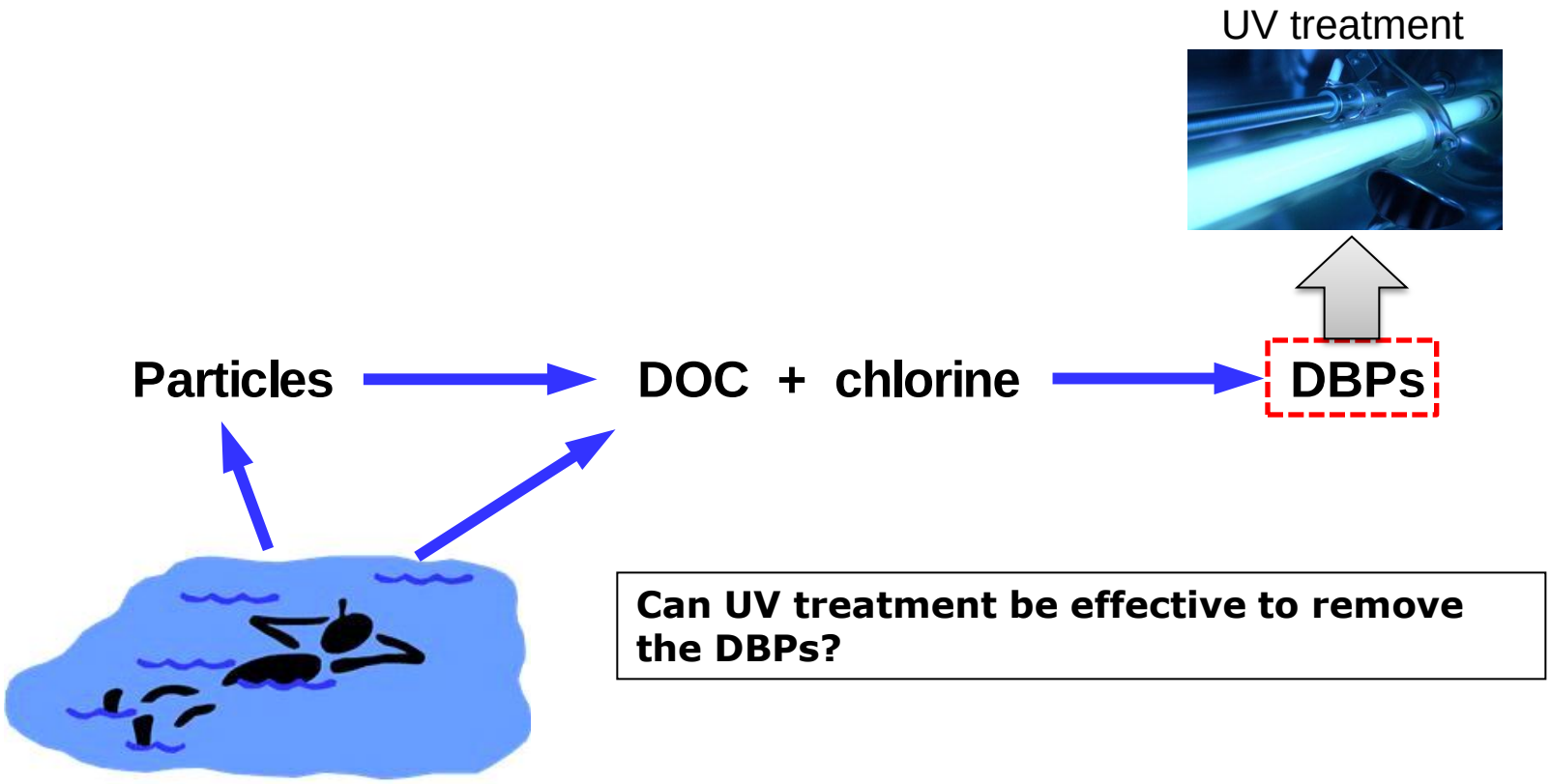
	Typical Seawater	Eastern Mediterranean	Arabian Gulf at Kuwait	Red Sea at Jeddah
Chloride (Cl^-)	18.980	21.200	23.000	22.219
Sodium (Na^+)	10.556	11.800	15.850	14.255
Sulfate (SO_4^{2-})	2.649	2.950	3.200	3.078
Magnesium (Mg^{2+})	1.262	1.403	1.765	742
Calcium (Ca^{2+})	400	423	500	225
Potassium (K^+)	380	463	460	210
Bicarbonate(HCO_3^-)	140	-	142	146
Strontium (Sr^{2+})	13	-	-	-
Bromide (Br^-)	65	155	80	72
Borate (BO_3^{3-})	26	72	-	-
Total dissolved solids (TDS)	**34.483**	**38.600**	**45.000**	**41.000**

$HOCl + Br^- \rightarrow HOBr + Cl^-$

$HOBr + DM \rightarrow$ Br-DBPs

Seawater pools disinfection resulted in brominated DBPs

Approach
Emerging treatment technologies



Can UV treatment be effective to remove the DBPs?

Approach
DBPs

Group	Compound	Abbreviation
THMs	Chloroform	TCM
	Bromodichloromethane	BDCM
	Dibromochloromethane	DBC
	Bromoform	TBM
HANs	Dichloroacetonitrile	DCAN
	Bromochloroacetanotile	BCAN
Misc. DBPs	Trichloronitromethane	TCnitro
	Dichloropropanone	DCprop
	Trichloropropanone	TCprop
HAAs	Bromochloroacetic acid	BCAA
	Dibromoacetic acid	DBAA
	Tribromoacetic acid	TBAA
	Dibromochloroacetic acid	DBCAA

Approach
Toxicity estimation

- Calculated for water samples by:

$$Toxicity = \sum \frac{C_i}{EC_{50,i}}$$

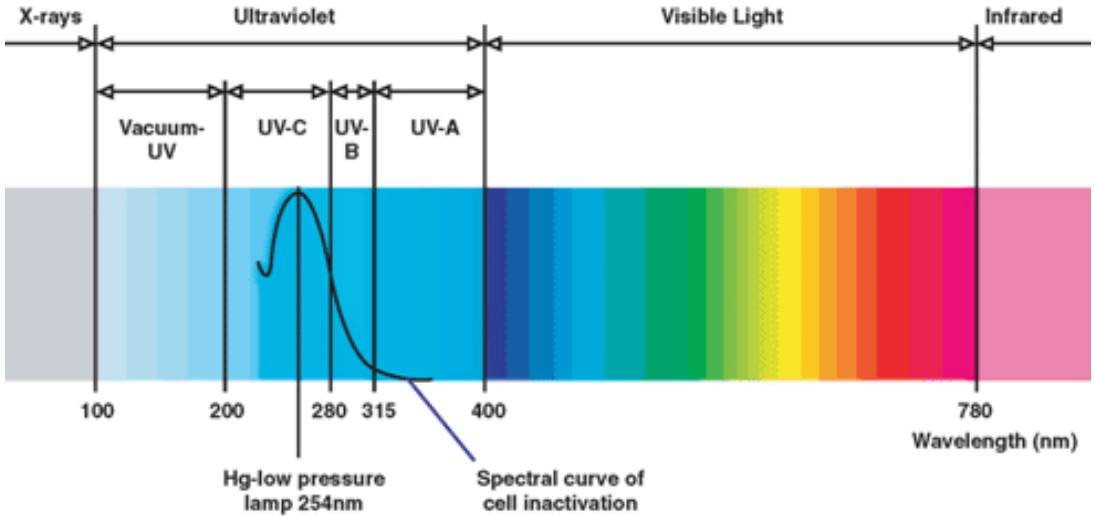
EC_{50} taken from Plewa et al. 2008

- The toxicity of the different groups

Haloacetonitriles (HANs) > Haloacetic acids (HAAs) > Trihalomethanes (THMs)

UV light

- UV light is short waved, high energy electromagnetic irradiation



Drinking water

- Low pressure UV is used for bacteria control

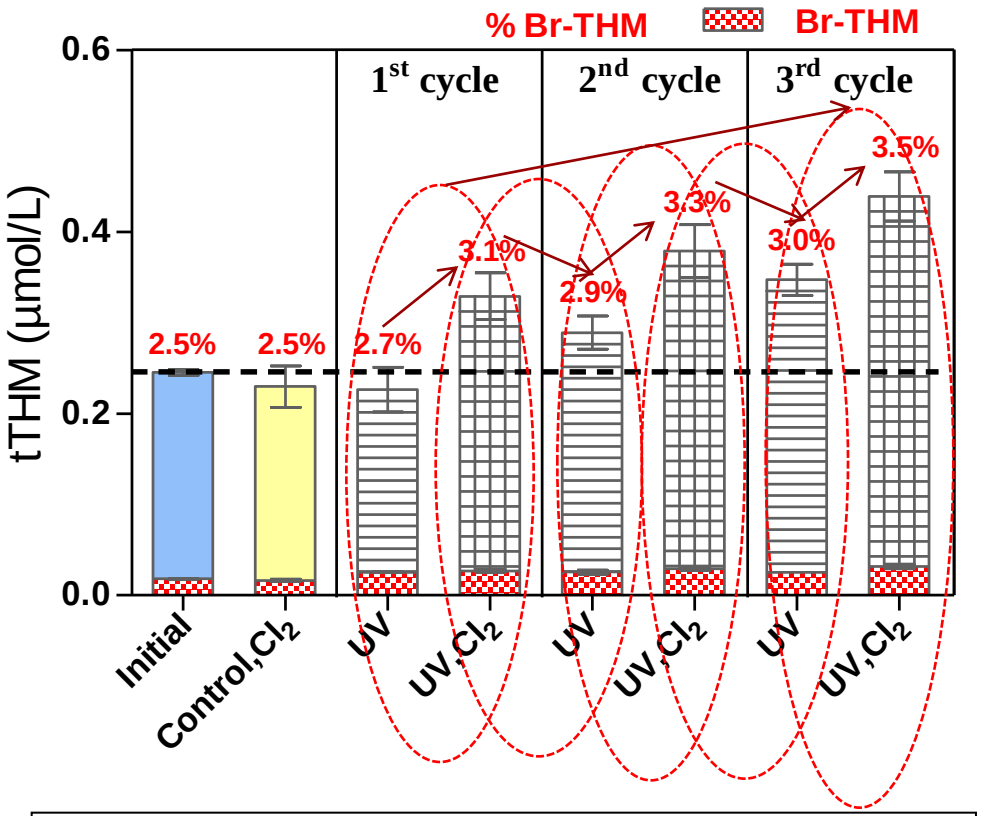
Swimming pools

- Medium pressure UV is used for combined chlorine control

UV photolysis

Freshwater pools

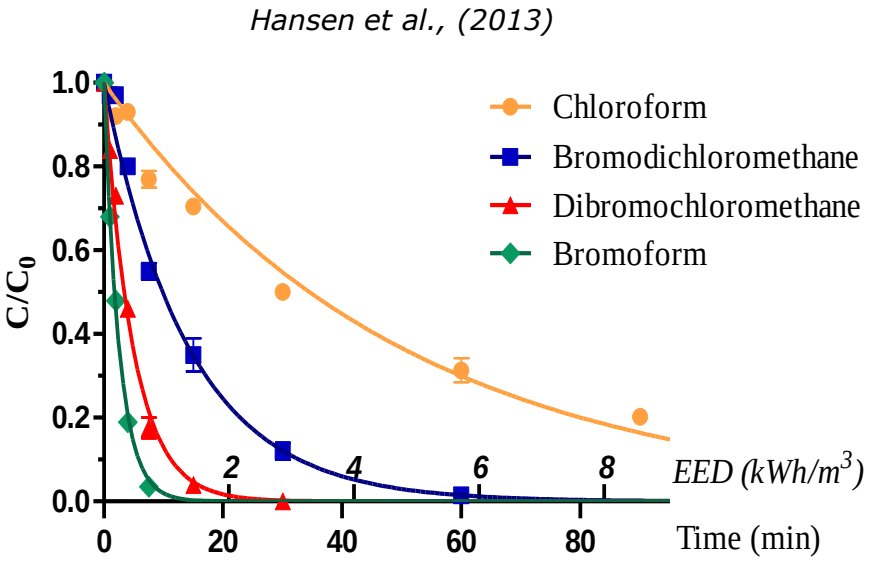
Total Trihalomethane



UV treatment followed by Cl_2 → increased Br-THM

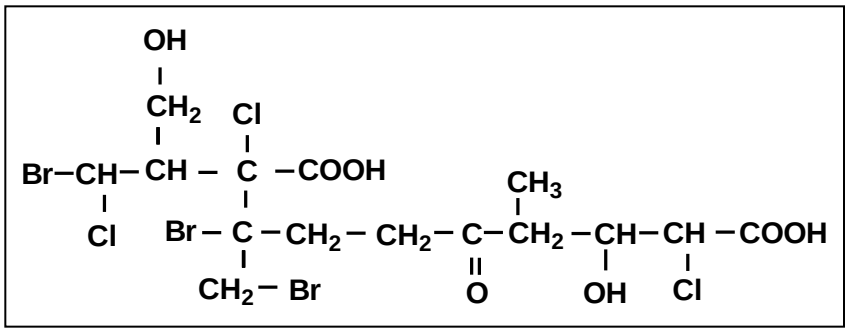
UV treatment → decreased Br-THM

UV photolysis



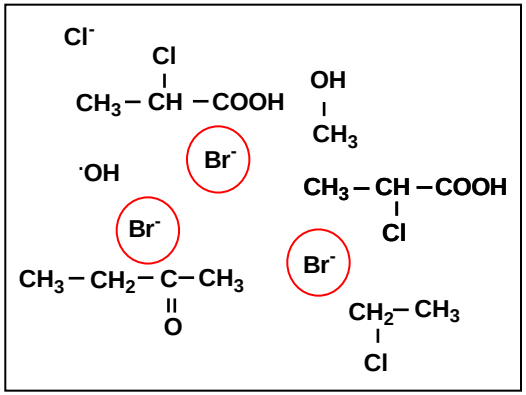
- Increased bromine substitution → increasing UV photolysis

Br-Cl-DBP Formation Theory

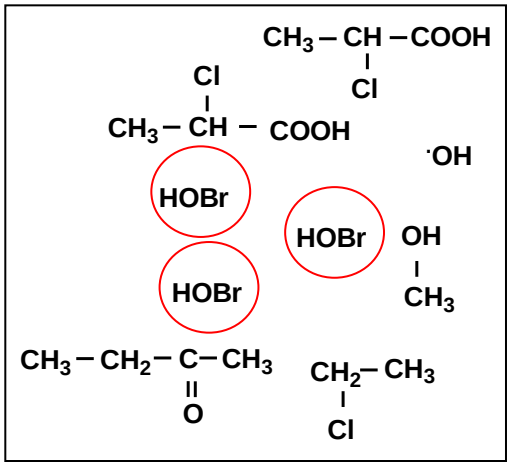


UV Irradiation

Reaction I

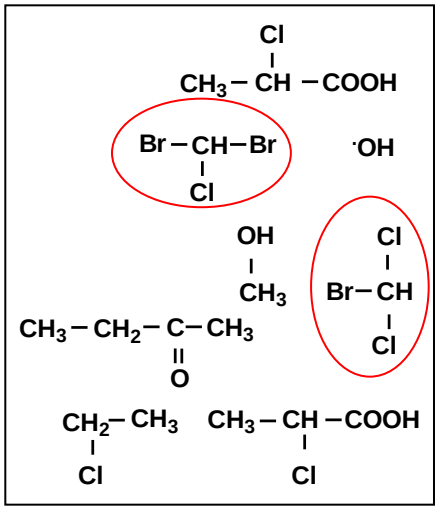


Cl_2 Reaction II



Further reaction

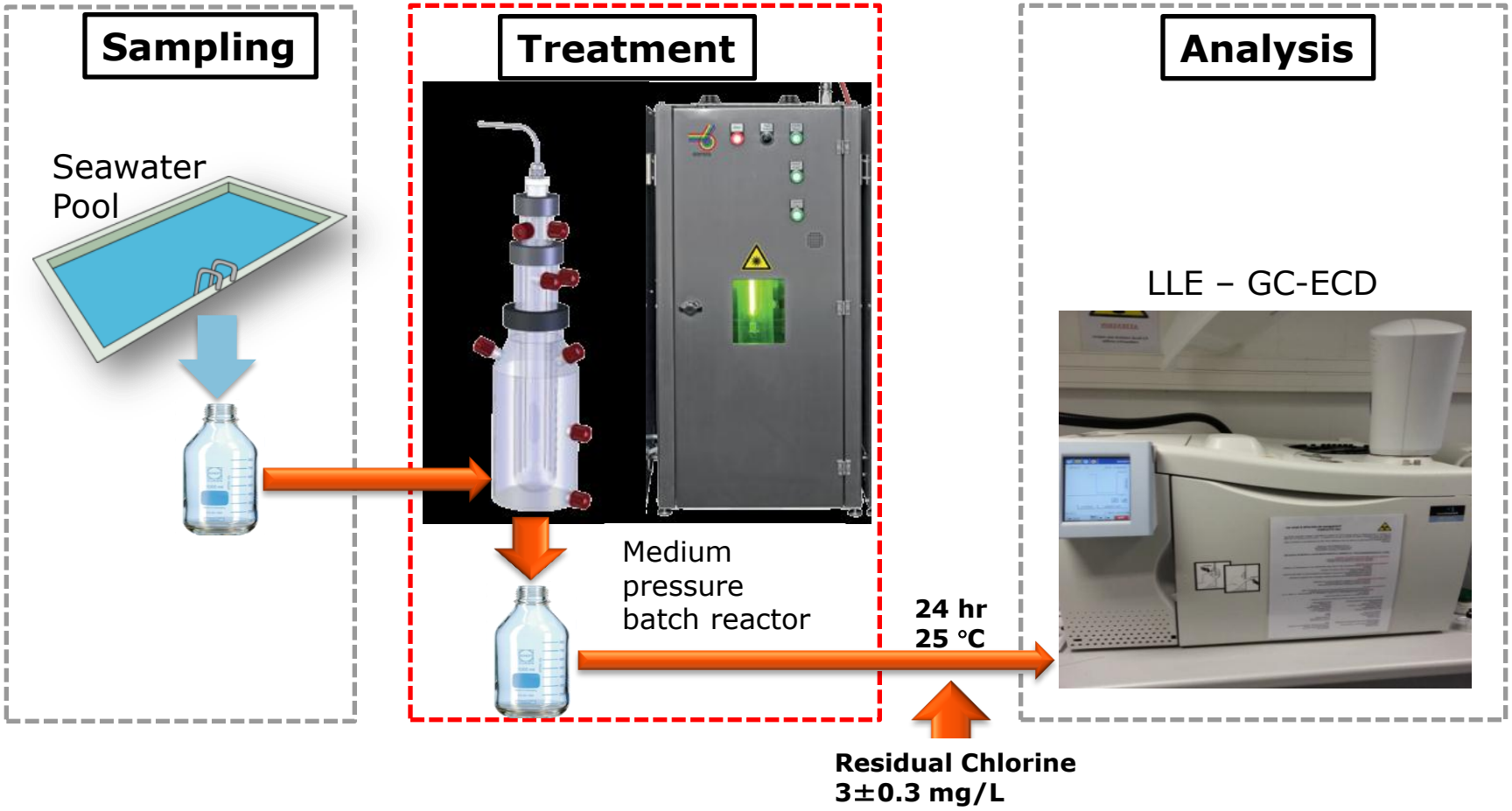
Reaction III



Spiliotopoulou et al., (2015)

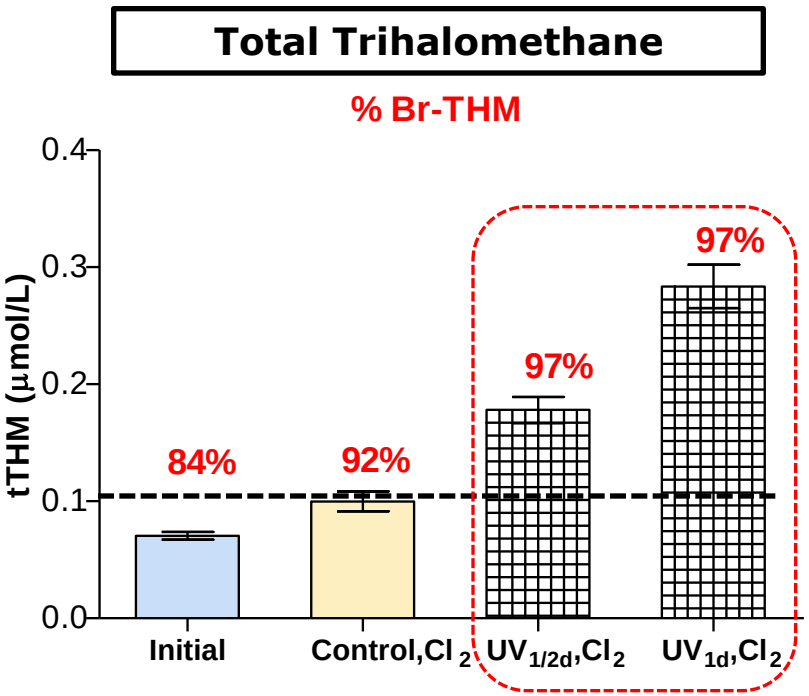

ATLANTIC OCEAN
FRANCE
SLOVENIA
CROATIA
Ligurian Sea
Gulf of Lion
ITALY
Adriatic Sea
Corsica
Tyrrhenian Sea
Strait of Otranto
ALBANIA
Bosphorus
Sea of Marmara
Thracian Sea
Dardanelles
GREECE
TURKEY
Aegean Sea
SPAIN
PORTUGAL
Balearic Sea
Balearic Islands
Sardinia
MEDITERRANEAN
Sicily
Ionian Sea
Strait of Messina
Sea of Sicily
Myrtoan Sea
Gulf of Antalya
Strait of Gibraltar
Alboran Sea
SEA
Sea of Crete
Crete
MALTA
Cyprus
Gulf of Gabès
Libyan Sea
Levantine Sea
ALGERIA
TUNISIA
MOROCCO
Gulf of Sidra
LIBYA
EGYPT

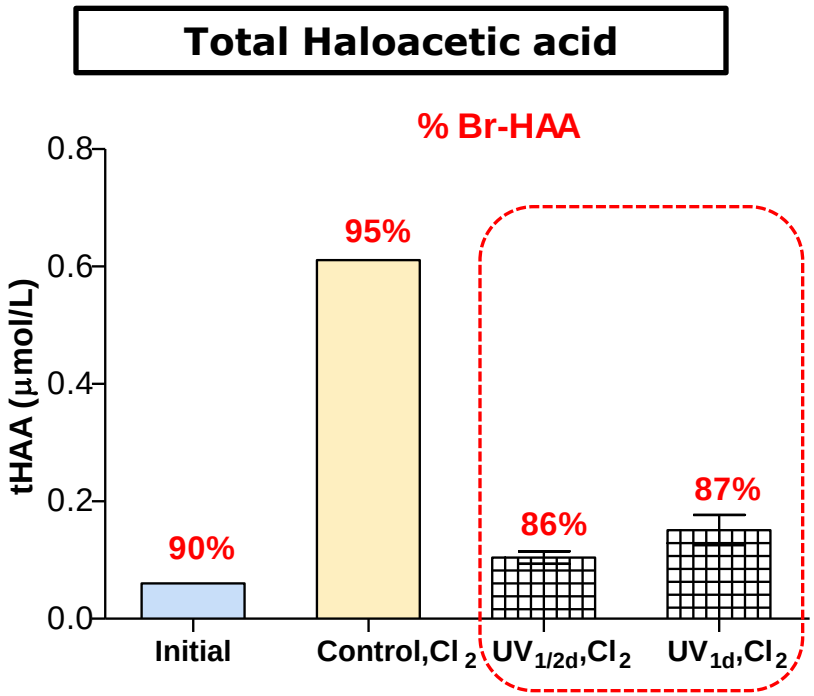
Experimental setup



UV in seawater pools

Results





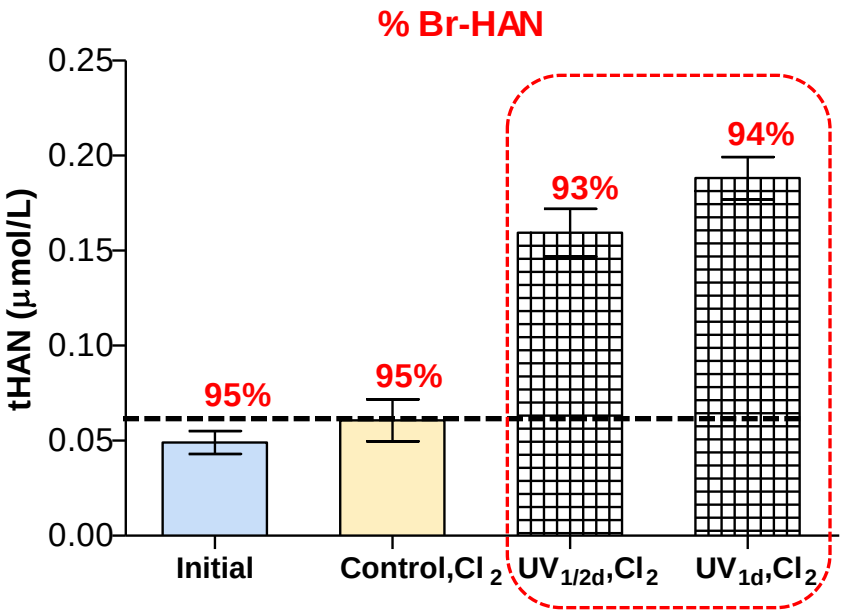
- UV treatment followed by Cl_2 → increased total THM

- UV treatment followed by Cl_2 → decreased total HAA

UV in seawater pools

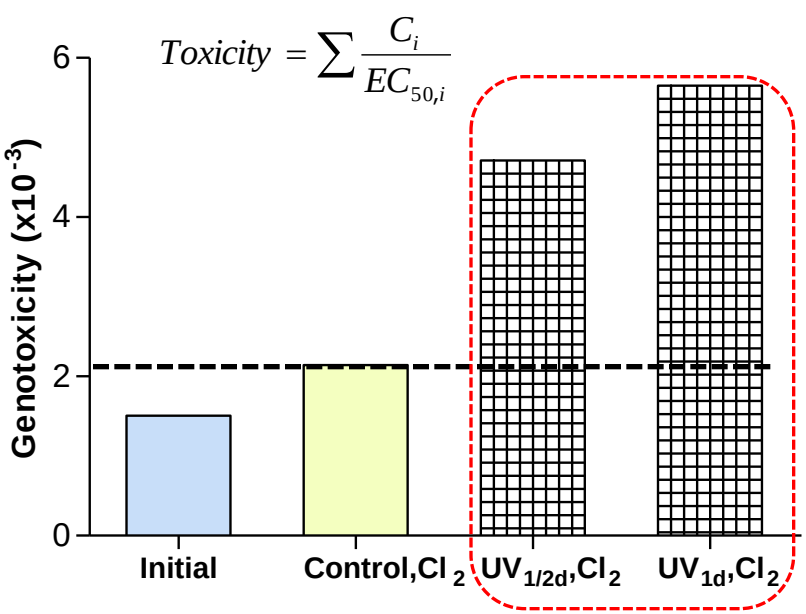
Results

Total Haloacetonitriles



- UV treatment followed by Cl_2 → increased total HAN

Genotoxicity



- UV treatment followed by Cl_2 → increased toxicity

Future work

Seawater pools

- Repeated treatment investigations for seawater pools

Thanks for your attention!